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50X1-HUM

Title: THE THERMAL FORM OF MOTION IN SUBTERRANEAN WATERS (USSR)

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Source: Doklady Akademii Nauk SSSR, Vol LXXIII, No 3, pages 565 - 569

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THE THERMAL FORM OF MOTION IN SUBTERRANEAN WATERS

P. F. Shvetsov

/Note: The following report, which appeared in the Hydrogeological Section of Doklady Akademii Nauk SSSR Vol. 73, No. 3 (1950), concerns the significance of thermal forms of convective motion to any study of circulation and supply of underground water in mountainous regions, that flow along large channel-like systems of tectonic fissures and interstices/.

The appearance of underground water springs in the bed or valley of a mountain river at heights 800-1200 meters above sealevel, in which the water rises along fissures of tectonic origin and has a higher temperature than river or ground water, is usually considered by hydrogeologists to be an indication of the presence of a deep water-bearing level under pressure. According to generally-accepted notions, the source of this water-bearing level must be situated considerably above the discharge zone (the spring), which was localized by a tectonic fracture, e. g., a fault. In other words, the ascending source is supposedly caused by a moving head of underground water circulation

$$\Delta P = h_a - h_b$$

where h_a is the head of the water level in the source region with respect to some arbitrary plane ~~of comparison~~ reference and h_b is the head of the discharge zone, i.e., the top of the ascending spring over this plane.

It is clear that the moving circulation head ΔP must be greater than the sum of the pressure losses caused by the resistance which must be overcome by the underground water current.

However, currents of comparatively warm underground waters have also been observed ascending along fault fissures where there are no source regions located considerably above the discharge zone of these waters. This refers to water-bearing formations which are found in fault fissures of the type

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which intersect beds and valleys of mountain rivers and create abundant ascending springs, above which there are only mountain peaks and ridges made up of impermeable rocks (frozen rocks, for example). Rainwater does not infiltrate the rocks composing these peaks and ridges because the fissures in these rocks are filled with clayey material or ice; rain flows off quickly and rapidly along the steep slopes of the peaks and ridges into the beds of adjacent rivers.

We may also add that in northern Siberia at elevations of 2000-3000 meters, atmospheric water exists for extremely short periods in the liquid state. Similar physico-geographical and hydrogeological conditions are not unusual.

Judging from purely hydromechanical laws, we must locate the source of underground water which rises along fault fissures to the bed or valley surface of a mountain river, under the conditions just described, in the surrounding heights. It seems to us, however, that we can no longer be satisfied with this assertion which assumes the existence of some hypothetical source region which is not actually observed.

Some thermodynamic processes are of great importance for the case of vertical circulation of ground waters along fault-gap fissures under the conditions described above. The author is convinced that if the valley and bed of a mountain stream is crossed by a deep fracture line with a system of tectonic fissures, there is often observed below this line a profuse ascending spring, even though the mountain peaks and ridges surrounding this section are composed of impermeable rocks (see Figure 1). The water temperature of such springs is considerably higher than the temperature of the river and ground water filling the bed and the alluvial deposits of the upper section of the mountain river.

Moreover, the main flow of the river section situated slightly above the ascending spring disappears, i.e., it is lost in the pebble deposits which cover the system of tectonic fissures.

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Analysis of these facts led to the supposition that the systems of fissures connected with fractures in the rocks composing the original river bed include within themselves both the source and discharge regions of deep-bearing formations under pressure.

The gravitational water filling the fracture fissures is "stratified" into two jets that move in two opposite directions, ascending and descending. This is caused by the great temperature difference of water at the earth's surface and water at depths measured in kilometers.

This temperature difference creates a difference of densities of the fissure water, a necessary condition for the convective heat exchange which takes place when the cold and warm jets move past each other.

The cold and dense river or ground water descends along a system of vertical tectonic fissures, while the hot water or warm gas-water emulsion of the deep water-bearing formation has low densities, and hence rises. The emergence of a gas-water emulsion at great depths is connected not only with chemical interaction of the water solution with the rocks containing it, or the entry of gases from the surrounding and underlying rock into the water, but also with the separation of gas bubbles from the cold surface water as it moves downwards along tectonic fissures and becomes warmer. Therefore, the gas of many ascending springs of fissure waters is little different in composition from atmospheric air.

The difference in densities of cold river water, on the one hand, and the gas-water emulsion, on the other, creates the moving head of water circulation along fault fissures. This condition can be roughly expressed by the following equation:

$$\Delta P = h(\gamma_v - \gamma_{sm}),$$

where h is the depth to the roof of the water-bearing formation under pressure from the water level in the river, γ_v is the specific weight of the cold river water, and γ_{sm} is the specific weight of the hot water or gas-water emulsion rising from great depths along fissures.

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Water-bearing formations under pressure are often found in fissured karstic limestones covered by clayey slates. The presence of free gas bubbles in water of ascending springs has been established.

The thermal and hydraulic interaction of river and ground cold water currents with warm and hot water masses contained in fissures of deeply-bedded limestones is a process accomplished through a system of tectonic fissures which crosses the stratum of clayey slates.

The supposition which we have advanced is partially confirmed by laboratory experiments. A tube 5 mm in diameter and 500 mm long was filled with cold water; the lower end was connected to a pan containing water heated from below and the upper was connected with a free current of cold water, flowing along an inclined trough. Two currents moving in opposite directions were observed. The water which was heated from below moved upwards and flowed out along the inclined trough, giving way to the denser cold water which descended from above.

This process of vertical counter circulation of water along one channel having a small cross-section did not stop until the heat source was removed. When several such channels, i.e., fissure systems, are present, this process should be intensified.

Purely hydromechanical conditions governing the circulation of underground waters along deep tectonic fissures, i.e. the presence of a hydraulic gradient, are often supplemented and sometimes even completely replaced by thermodynamic conditions of temperature gradient. It should be clear, however, that this applies only to the circulation of underground waters along deep gaping tectonic fissures and is not applicable when we consider the movement of underground waters through pores in friable deposits and through narrow fissures in massive rocks.

It may be that thermodynamic condition, namely a temperature gradient, are also responsible for "water being drawn up from a region of pressure" to the top of an artesian slope, as shown in A. M. Ovchinnikov's drawing (see

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Figure 2). The other explanation (a source region located above the outer discharge zone) is of no importance in this case, since, judging from the diagram, water moves in free flow from the source region to the outer discharge zone. Only a descending movement of cold water from the source region along the artesian slope could cause the counter movement, i.e., a "drawing up", or more correctly a dislodgement, of the warm water from the region of pressure upwards to the outer discharge zone.

Undoubtedly, the thermal form of water movement also takes place in sandy and sandy loam water-bearing formations. That water is drawn up from heated (open) sections to cooled (shaded by a building or forest) sections has been established by observations. The shifting of ground water from the depths to the frozen shield when the soil freezes is also apparently a thermodynamic effect; it is caused by the water particles attempting to transfer to the lowest energy level.

Naturally, the process of convective heat exchange in a mass of water filling the pores of a sandy or sandy loam water-bearing formation is less sharply defined and takes place less rapidly than in a mass of water filling gaping fissures.

Submitted 13 May 1950, from the Institute of Permafrost Studies imeni V. A. Obruchev, Academy of Sciences USSR.

(Figures appended)

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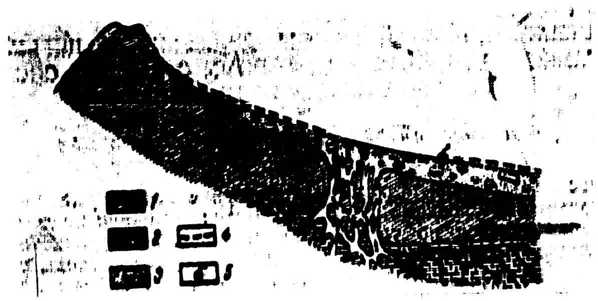

Figure 1. Diagram of the Circulation and Supply of Subterranean Waters Along Systems of Tectonic Fissures. 1 - Limestones, 2 - Clayey Slates, 3 - Pebble-Gravel Alluvial Deposits, 4 - Water Level in the River Bed, 5 - Head of the Ascending Spring (p. 566, text)

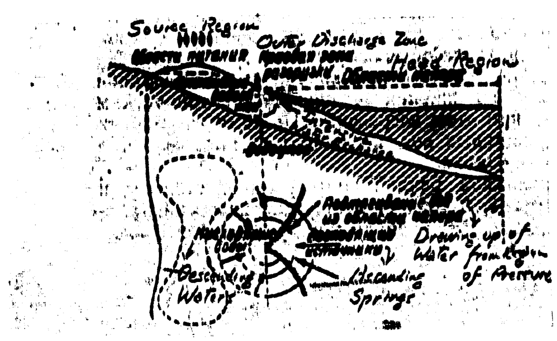

Figure 2. Diagram of the Circulation of Subterranean Waters in the Axial Belt and Within the Artesian Slope of a Mountainous Folded Region (According to A. M. Ovchinnikov) /p. 568, text)

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